21p.

FACILITY FORM 602

N65-35222
(ACCESSION NUMBER)

21
(PAGES)

TMX-51838
(NASA CR OR TMX OR AD NUMBER)

(THRU)
1

(CODE)
14

(CATEGORY)

Spectral Measurements on High Intensity Light Sources

Cat. 23

by

John C. Flemming & Charles H. Duncan

NASA Goddard Space Flight Center

Greenbelt, Maryland

GPO PRICE $ ______

CFSTI PRICE(S) $ ______

Hard copy (HC) 1.00

Microfiche (MF) .50

ff 653 July 65

ABSTRACT

35222

Measurements of the spectral distributions of a xenon, mercury-xenon, and carbon arc have been accomplished. The carbon arc and xenon arc have spectral distributions most similar to air mass zero solar irradiance. The absorptivities of gold, silver, and aluminum have been calculated using the measured spectral distributions. The per cent variations from the solar absorptivities of these materials vary from -3% to +26% for the xenon arc; -26% to +11% for the carbon arc; and, -8% to +77% for the mercury-xenon arc.

Author

[redacted]

Introduction

The Solar Simulation Group of the Thermal Systems Branch has developed and calibrated an instrumentation for measuring the spectral characteristics of any light source. The calibration of the instrument was accomplished by using a strip-filament tungsten lamp calibrated by the National Bureau of Standards. The uncertainty of the calibration of this lamp varies from 3 per cent in the infra-red to 8 per cent in the ultraviolet(1). This instrumentation uses a Leiss double monochromator as the dispersing element and has been previously described(2). The instrumentation and techniques of data acquisition have been developed to a point which allows repeatability of results to 1 per cent or less on measurements of light sources comparable to the standard lamp. The instrumentation has been used to calibrate one N.B.S. standard lamp in terms of another N.B.S. standard lamp. The results obtained were in agreement to the N.B.S values within 1%.

In measurements of the spectral distributions of campact arc sources and carbon arcs, complications are encountered which are not present in tungsten strip filament lamps. The complications are: the non-uniformity of the source, the instability of the source, and the extremely high spectral radiances of the source. The micro brightness contours of a xenon[3] and mercury-xenon[4] source vary by a factor of 3 to 4 between the cathode of the lamp and a point 1.0 mm. removed from the cathode toward the anode. The stability of these micro brightness contours in time has been studied qualitatively, and variations are evident which will produce significant errors if the position of the arc focused on the entrance slit of the monochromator is not held to tolerances of 1/10 mm. or less. To accomplish this repositioning of the instrumentation repeatedly is very difficult, if not impossible. The spectral radiances produced by these lamps are as much as 6 orders of magnitude greater than the spectral radiances produced by the standard lamp. This introduces large scaling factors which can become a source of uncertainty.

All the preceding discussion related to absolute spectral radiance measurements. If the primary interest in a source is the spectral distribution only, then a relative spectral energy determination will suffice. Relative energy determinations are not as strongly dependent upon variation in arc characteristics because the source can be focused at a convenient position in the optical train which does not have to be the entrance slit of the monochromator. This minimizes the arc fluctuations described above. Also, the extreme differences in spectral radiances between the standard and the unknown source can be reduced by neutral filters whose transmission characteristics do not have to be known.

The collection of energy[1] incident to the entrance slit of the monochromator can also be varied by an aperature which changes the effective f/no of the entrance optics. In this manner, scans of individual spectral regions can be accomplished and then normalized to yield a complete spectral distribution curve.

Experimental Procedure

Two methods of illumination of the entrance slit of the monochromator have been used. These are diagrammed in Figure 1. In Method A, radiation from the lamp is introduced onto a block of magnesium oxide by means of a front-surfaced aluminum mirror. The MgO block is then focused onto the entrance slit of the monochromator by means of a spherical mirror and turning flat. Corrections for the reflectivity of MgO and the other optical elements have been made in the data presented. In method B, radiation from the lamp is focused at a point about nine inches ahead of the entrance slit in the optical train. This is accomplished by the optical components shown. This allows divergent illumination to be incident upon the slit of the monochromator. This means that the radiation has a different optical path through the instrument than it does when an image is formed at the slit. This also means that a different area of the detector will be illuminated than that when the calibration was performed. This introduces no errors which are wave length selective according to a recent paper[5].

The detectors used in obtaining this data were: (1) 1P-28 photomultiplier, (2) 9592B photomultiplier, (3) 7102 photomultiplier, and (4) lead sulfide cell. The bandwidth of radiation passed by the instrument varied from 5A in the ultraviolet to 250A in the infra-red.

The data is recorded on a strip-chart recorder at present and about 500 points between 250 nm and 2500 nm are reduced. This is a very slow and tedious procedure and a procurement request has been initiated to provide a digital output from the Leiss which can be processed by a computer. A program has been written to process the data and compute spectral radiances; and, absorptivities of selected materials based on the spectral distribution measured.

Spectral Distribution Measurements

Spectral measurements have been obtained for an Osram XBO 1600 watt xenon lamp, an Hanovia 929B1 2500 watt mercury-xenon lamp, and a Genarco ME4 CWM carbon arc.

Figure 2 shows the spectral distribution obtained from the Osram lamp operated at 2500 watts using Method A of illumination shown in Figure 1 and described above. Figure 3 shows the spectral distribution of the same lamp operated at the same wattage but using Method B of illumination as described above.

Figures 4 and 5 show the spectral distribution obtained from the Hanovia lamp operated at 2500 watts. The method of illumination used was A and B respectively.

Figure 6 shows the spectral distribution of the Genarco carbon arc operated at 185 amperes. The method of illumination used was B. Carbons used were Lorraine Orlux.

Figure 7 is a plot of Johnson's data[6] plotted in a similar manner as the data above.

Figures 8, 9, and 10 are plots of the above data presented in a different manner. The per cent of the total energy per 10 nm bandwidth between 250 nm and 2500 nm is plotted against wavelength. Each of the above measurements using illumination method B is shown. A plot of Johnson's data is shown on each curve for comparison purposes. The areas under the curves are the same for each figure for both the solar irradiance and the respective lamp. An inspection of these three figures shows that the source most similar to the air-mass zero solar irradiance is the carbon arc with xenon next and mercury-xenon last. The carbon arc is deficient in the ultraviolet and part of the infrared; the xenon is deficient in the visible and infrared except for the strong excess between 800 and 1000 nm; the mercury-xenon is deficient in the visible except for the strong emission lines of mercury around 420 nm and 580 nm. If a filter were manufactured which would eliminate the excess energy of xenon betwen 800 nm and 1000 nm, then xenon would approach or surpass the carbon arc in suitability of spectral characteristics.

The data presented in Figures 8, 9, and 10 have been used to calculate the absorptivities of gold, aluminum, and silver. The spectral band widths used for these calculations were: 20 nm from 250 nm through 600 nm; 50 nm from 600 nm through 1000 nm; and 100 nm from 1000 nm through 2600 nm. The values for the reflectivities of the materials were obtained from the American Institute of Physics Handbook for 1957, Table 6K-4. The values for air-mass zero solar irradiance are from Johnson [6] and were used to calculate the solar absorptivities.

The results of these calculations are:

Source	Gold	Silver	Aluminum
Solar	19.2%	4.9%	7.9%
Xenon	18.7%	6.2%	8.4%
Hg-Xe	19.7%	8.7%	7.3%
Carbon Arc	21.3%	3.6%	7.7%

The deviations of absorptivity of each material from the solar absorptivity is summarized below:

Source	Deviation from Solar Absorptivity		
	Gold	Silver	Aluminum
Xenon	-2.6%	+26,3%	+6.2%
Hg-Xe	+2.7%	+77.1%	-7.7%
Carbon Arc	+11%	-26.5%	-2.6%

A study of this table reveals that for these three materials, the carbon arc and xenon will yield about the same absolute errors. It also shows that Hg-Xe is quite suitable if materials such as gold and aluminum are used. However, if silver is used, a much larger error will result with the mercury-xenon lamp. This points to the result that for thermal balance studies, the materials used can be strongly affected by the spectral characteristics of the simulation. So long as materials with uniform spectral absorptivities are used, the spectral characteristics of the source are of minor importance but when a material has a strong change in absorptivity with wavelength the spectral distribution of the simulator becomes quite important. These values of absorptivities are based on the data shown in Figures 8, 9, and 10 and are probably accurate to ±10% for sources of these types in general. It should be restated that the absorptivities discussed above relate only to the source and do not take into account the effects of any optical system which will be present in a simulator. The effect of adding an optical system is, in general, to attenuate the shorter wavelengths more than the longer.

References

1. Stair, Johnson, Halback; "Standard of Spectral Radiance for the Region of 0.25 to 2.6 microns"; J. of Res. NBS, Vol. 64A, No. 4., July-August 1960.

2. Flemming, Hobbs; "Calibration of the Leiss Instrumentation"; Conference on Solar Simulation Research and Technology, 1963.

3. Macbeth Sales Corporation; "Technitalk"; L-8, 4-62.

4. Hanovia Lamp Division; "Hanovia Compact Arc Lamps"

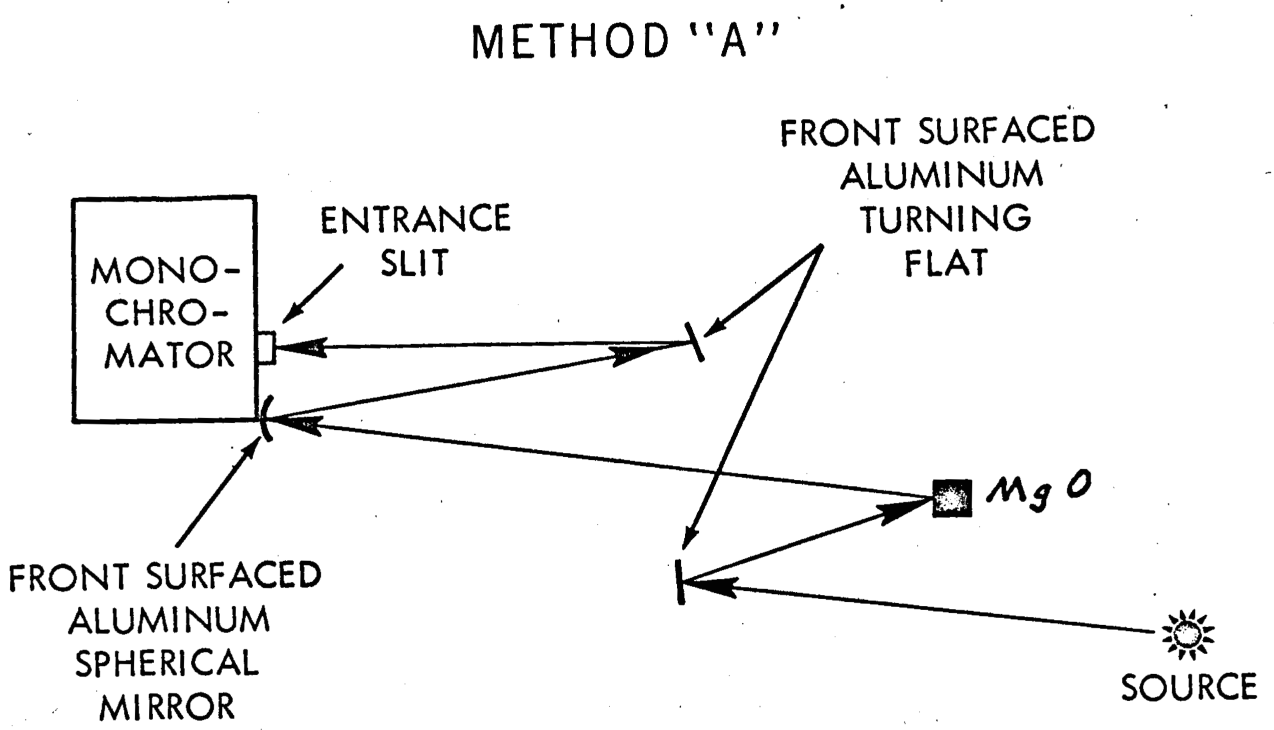
5. Stair, Schneider, Jackson; "A New Standard of Spectral Irradiance"; J. App. Opts.; Vol II, No. 5, Nov. 1963.

6. Johnson; "The Solar Constant"; J. of Met.; Vol. XI, No. 6, Dec. 1954.

Appendix

Operational Experience with Genarco Model ME4 CWM Automatic Reloading Carbon Arc

A Genarco carbon arc with an automatic reloading device has been operated for approximately sixty hours. The reloading mechanism is essentially a plunger which drives a female carbon onto a tapered male carbon. The joint holds together by friction, both male and female having been machined to fit very snugly. A disadvantage to this method is that each carbon has to be custom fitted in the sequence since no two are exactly the same. Another disadvantage is the fact that the alignment necessary between the carbons to be joined is very critical. In operation, about one of every three joinings is not accomplished because of misalignment of the two carbons. In some cases, the joining can be accomplished manually without shutdown of the arc and in some others fracture of the female carbon results which requires shutdown of the arc for correction. There is no mechanism for joining the negative carbons, the solution for long operation periods being the use of long negative carbons of the order of four feet in length. The stability of the arc has been measured using an Eppley normal incidence pyrheliometer. Variations averaged about five per cent. When a joining of the carbons was accomplished, a short term excess of about 15-25 per cent was noted which fell back to the normal level within one or two minutes. This is caused by slippage of the positive carbon in the feed mechanism due to the plunger action of the reloading mechanism. When a joint burns through, the variation is within the five per cent quoted above.



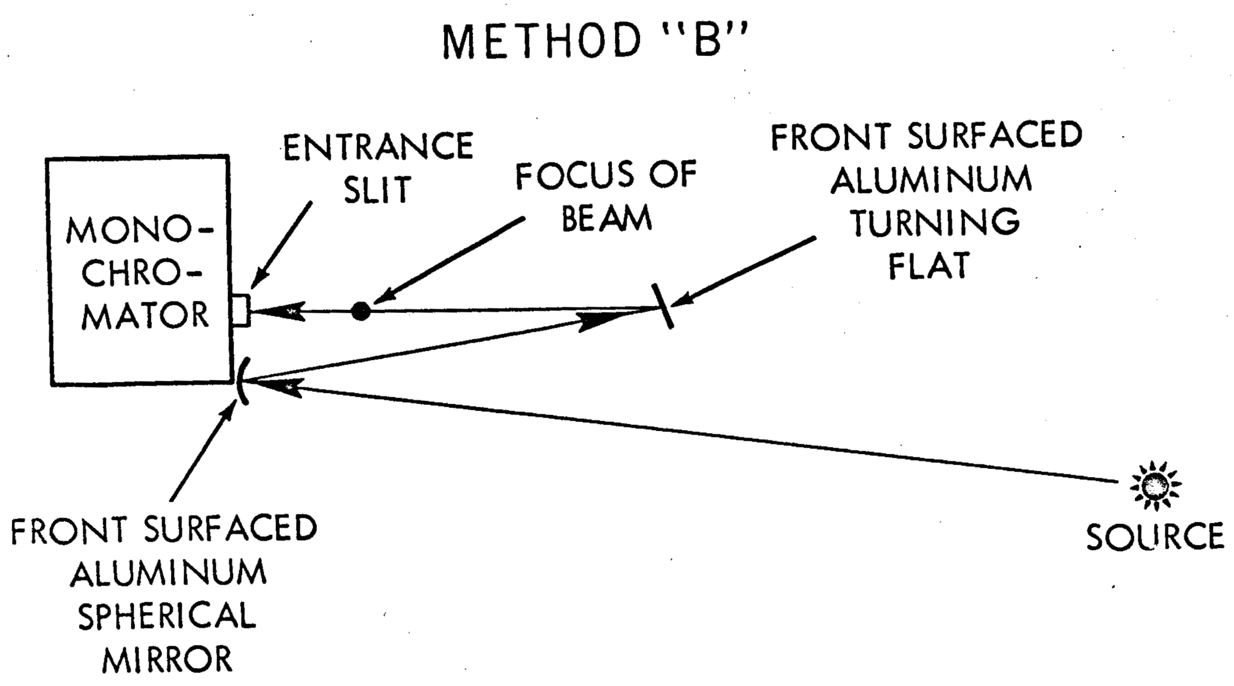


Fig. 1 - Optical Diagram

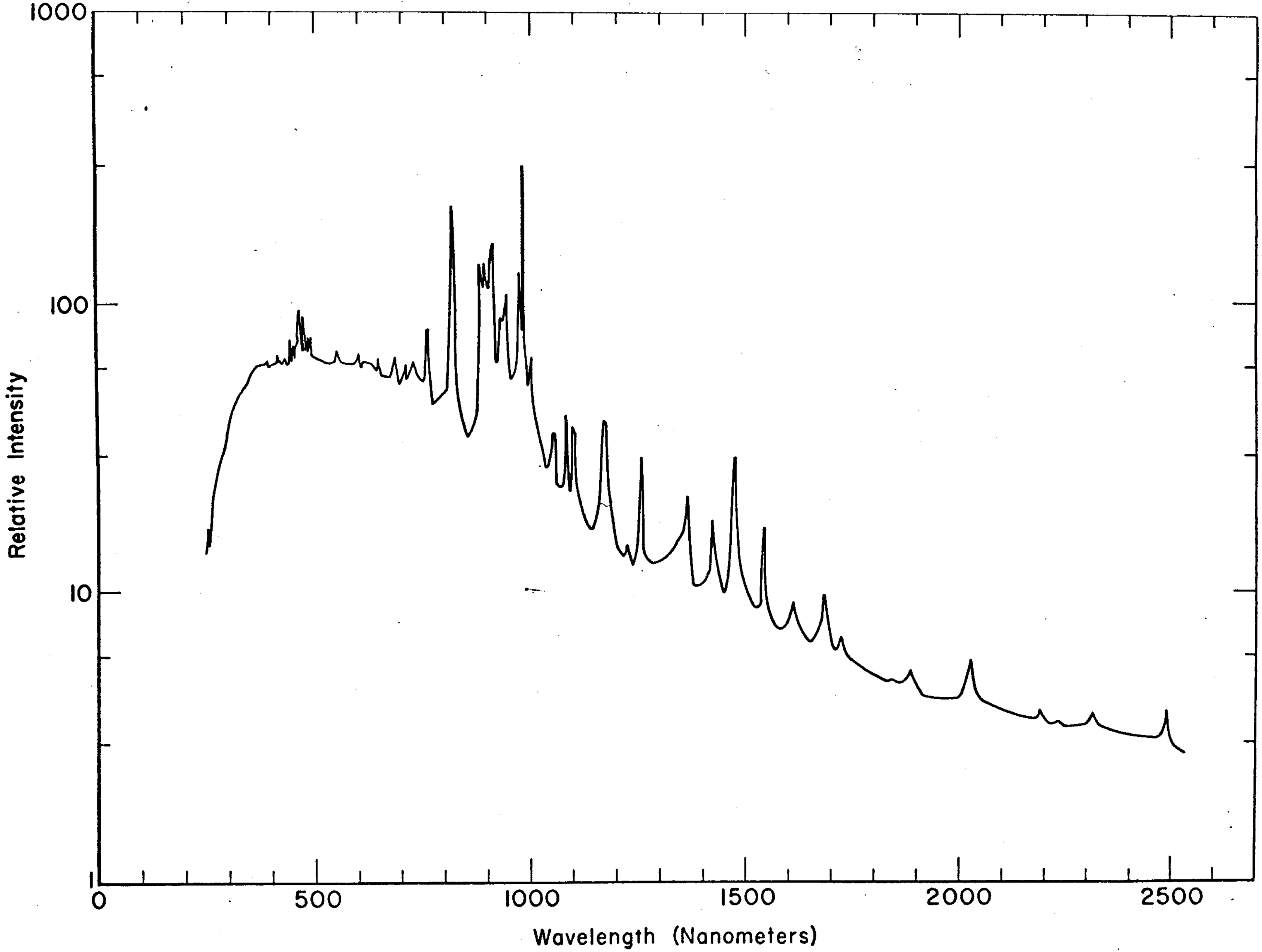


Figure 2. - Spectral Distribution of Xenon Lamp Operated at 2500 Watts, Illumination Method "A".

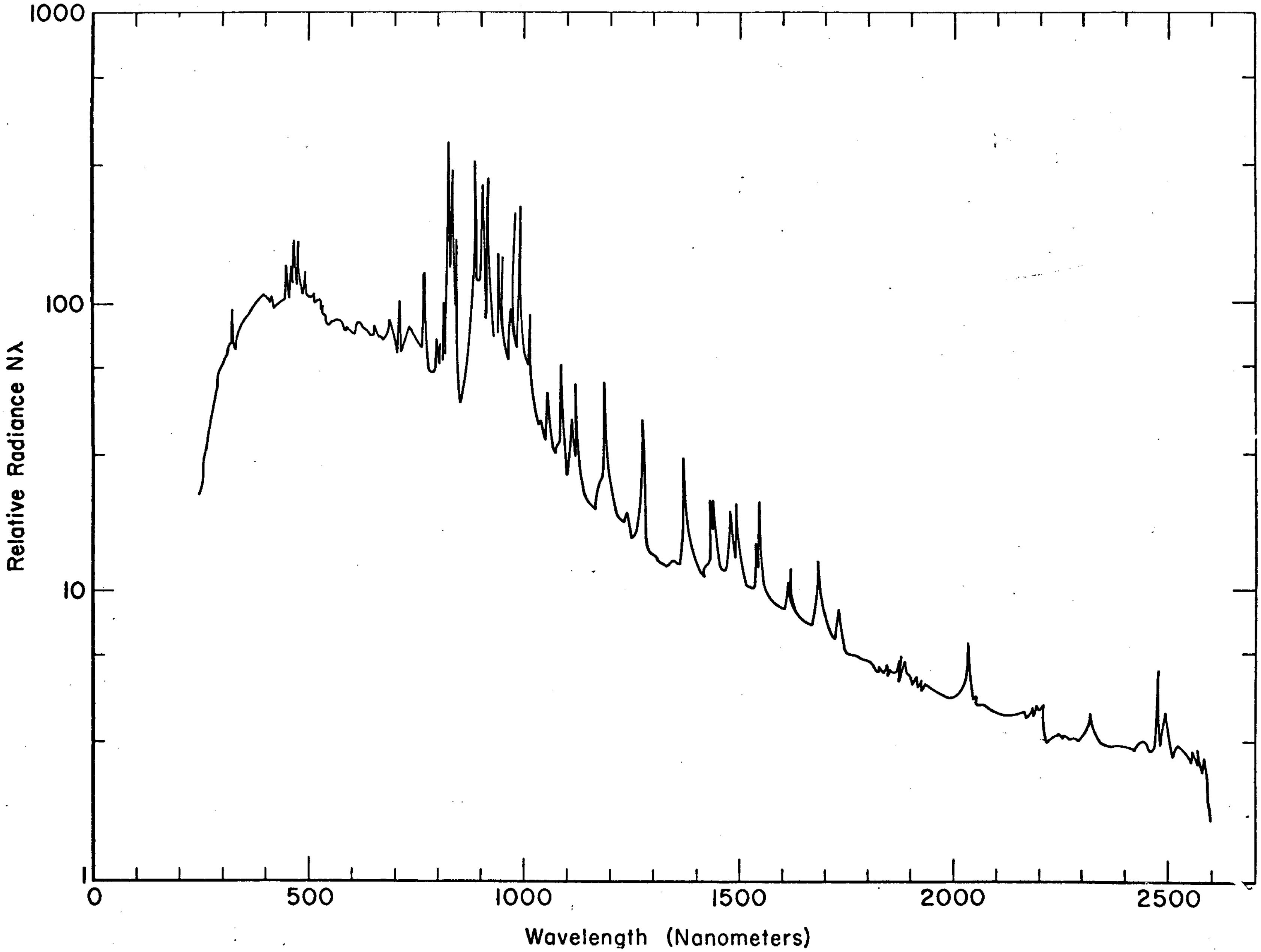


Figure 3 - Spectral Distribution of Xenon Lamp Operated at 2500 Watts, Illumination Method "B".

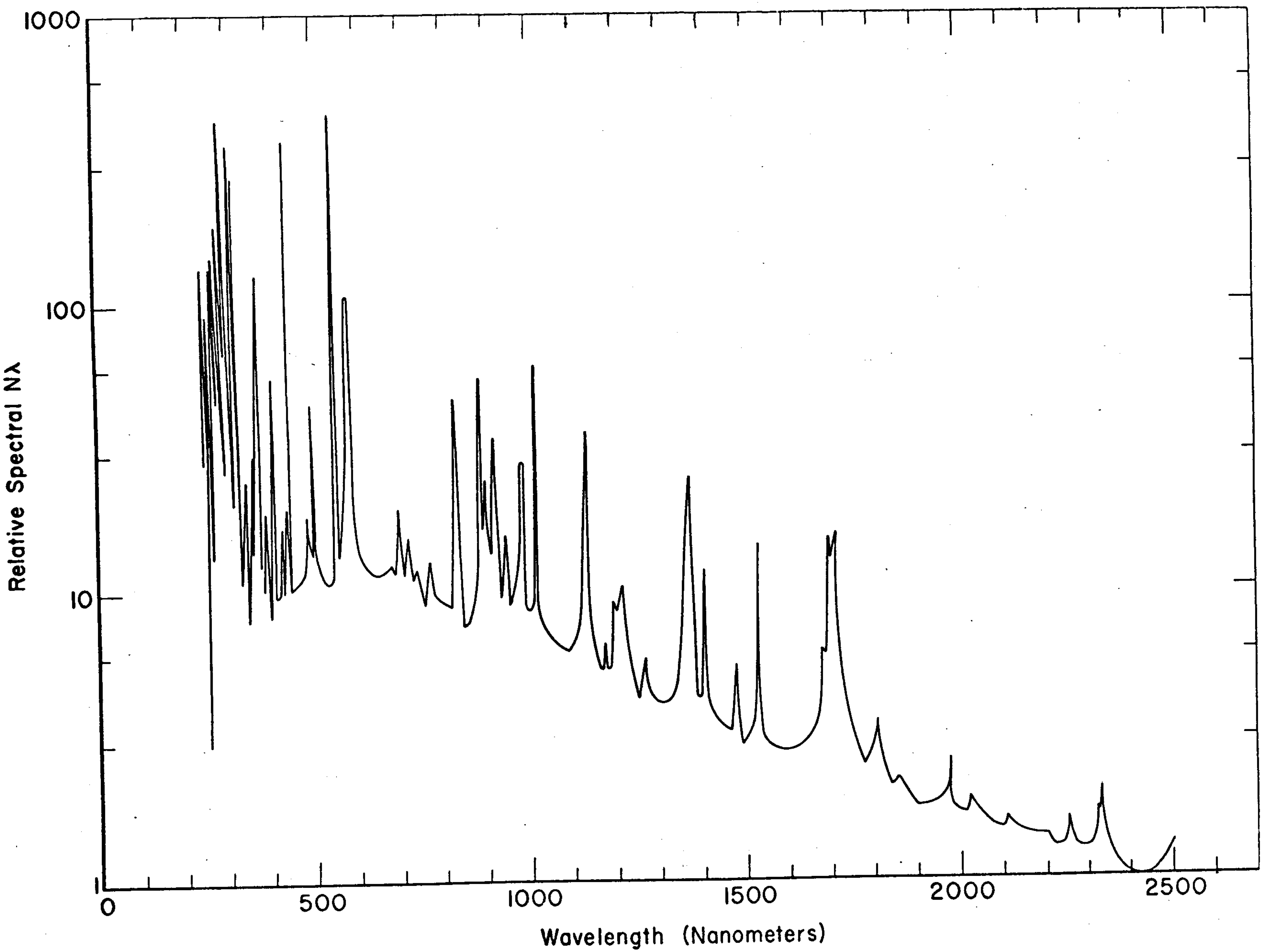


Figure 4 - Spectral Distribution of Mercury-Xenon Lamp Operated at 2500 Watts, Illumination Method "A".

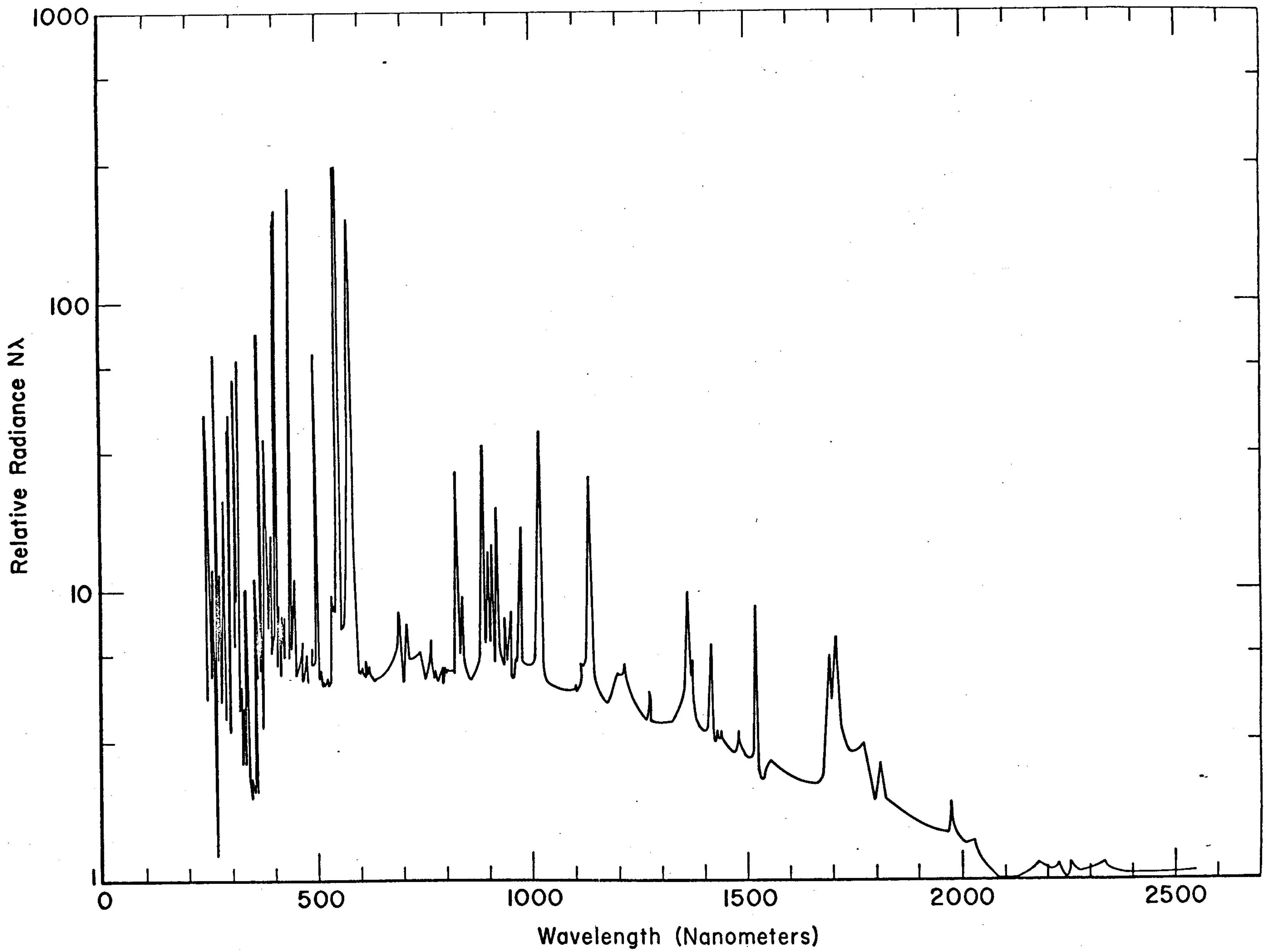


Figure 5 - Spectral Distribution of Mercury-Xenon Lamp Operated at 2500 Watts, Illumination Method "B".

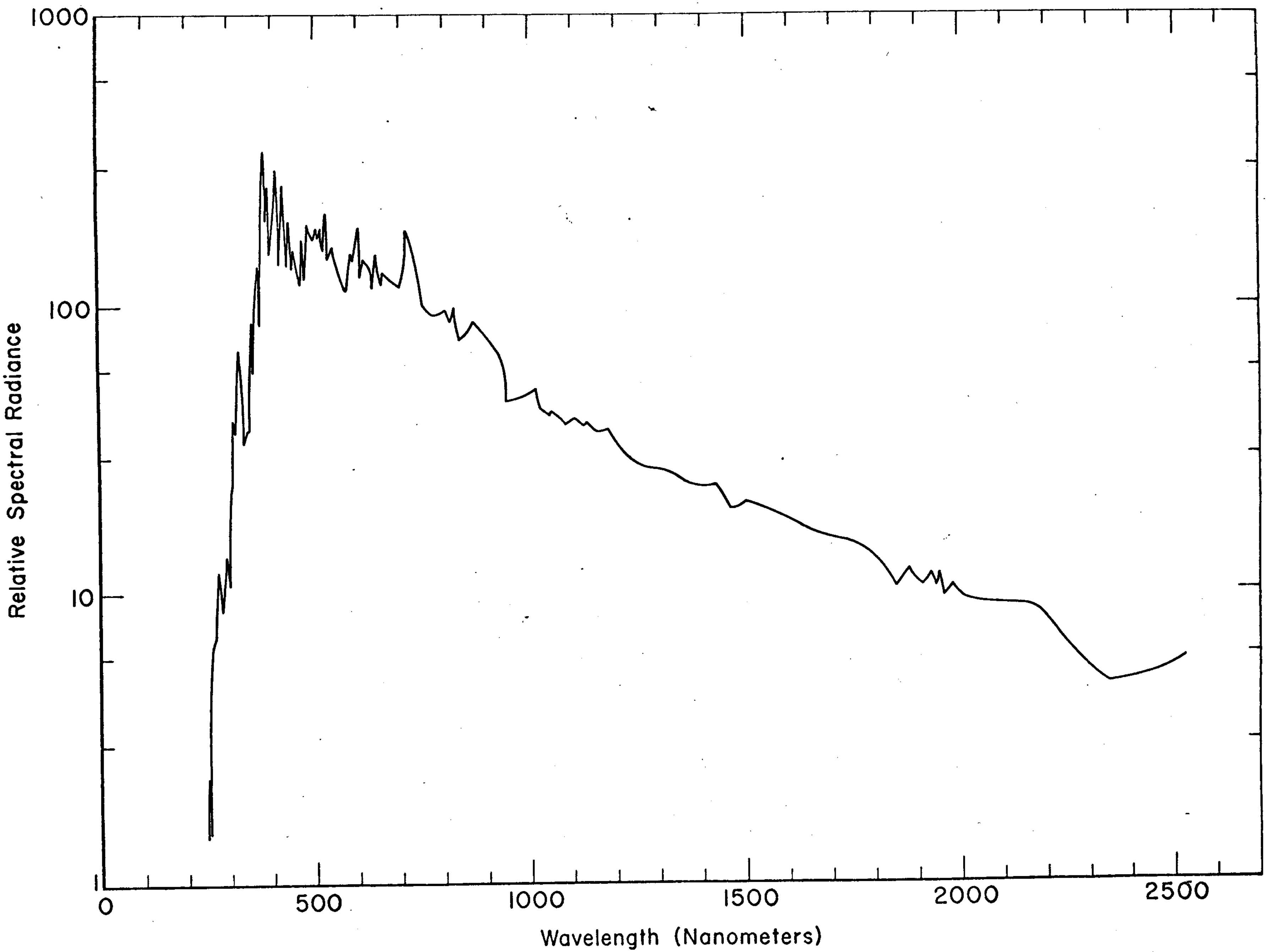


Figure 6 - Spectral Distribution of Carbon Arc Operated at 10,000 Watts, Illumination Method "B".

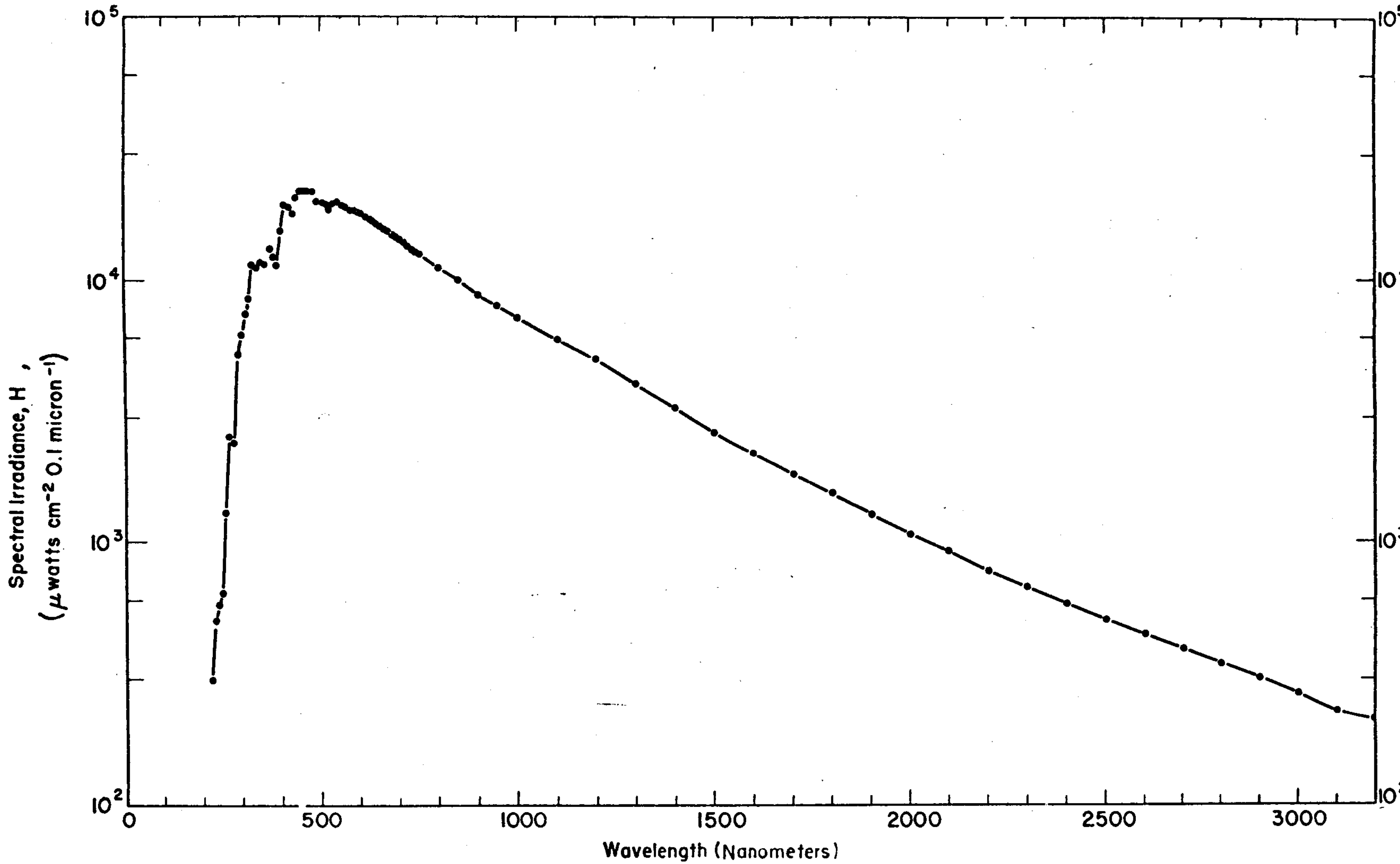


Figure 7 - Air Mass Zero Solar Irradiance (Johnson)

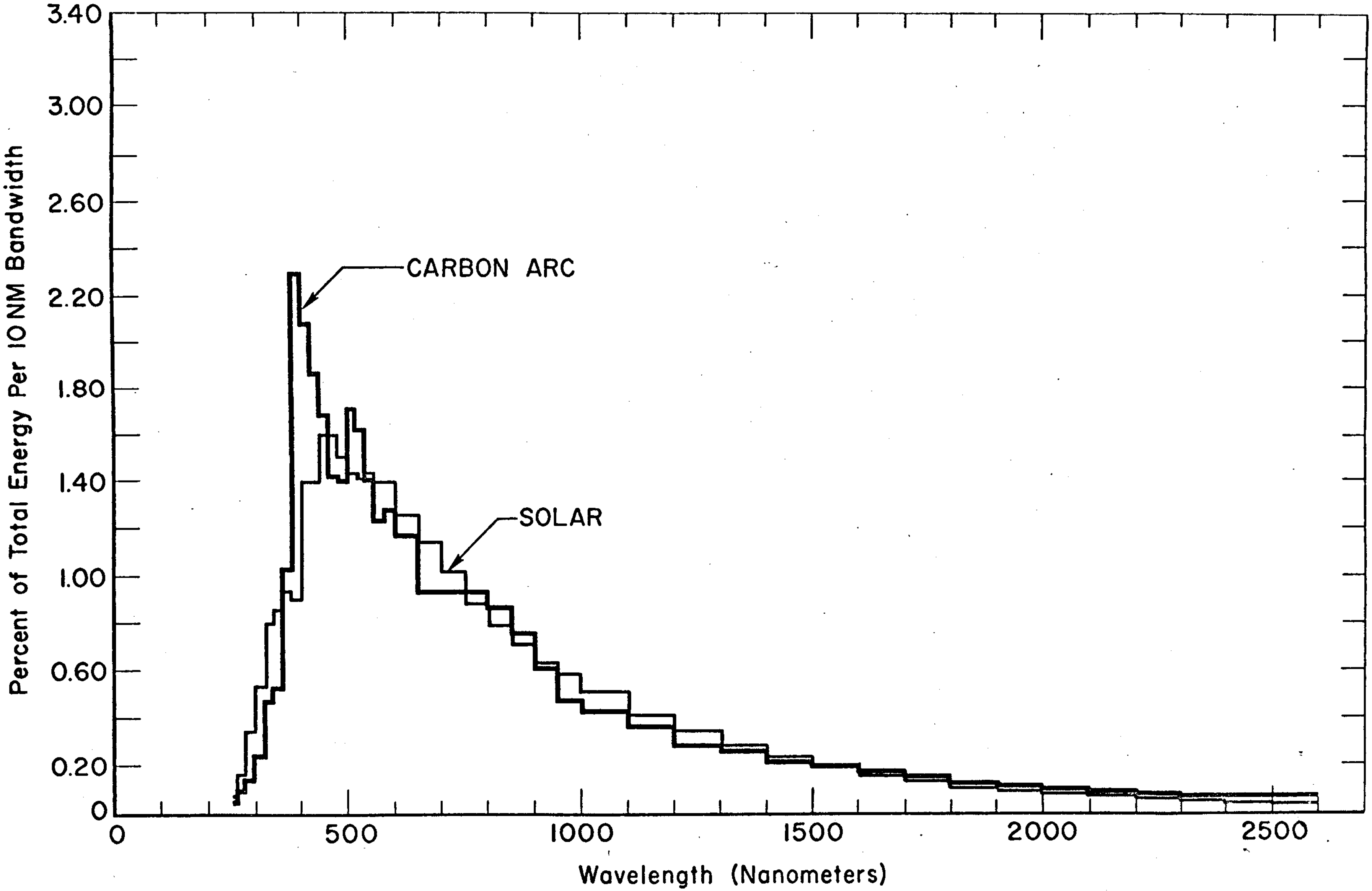


Figure 8 - Comparison of Carbon Arc Spectrum with Solar.

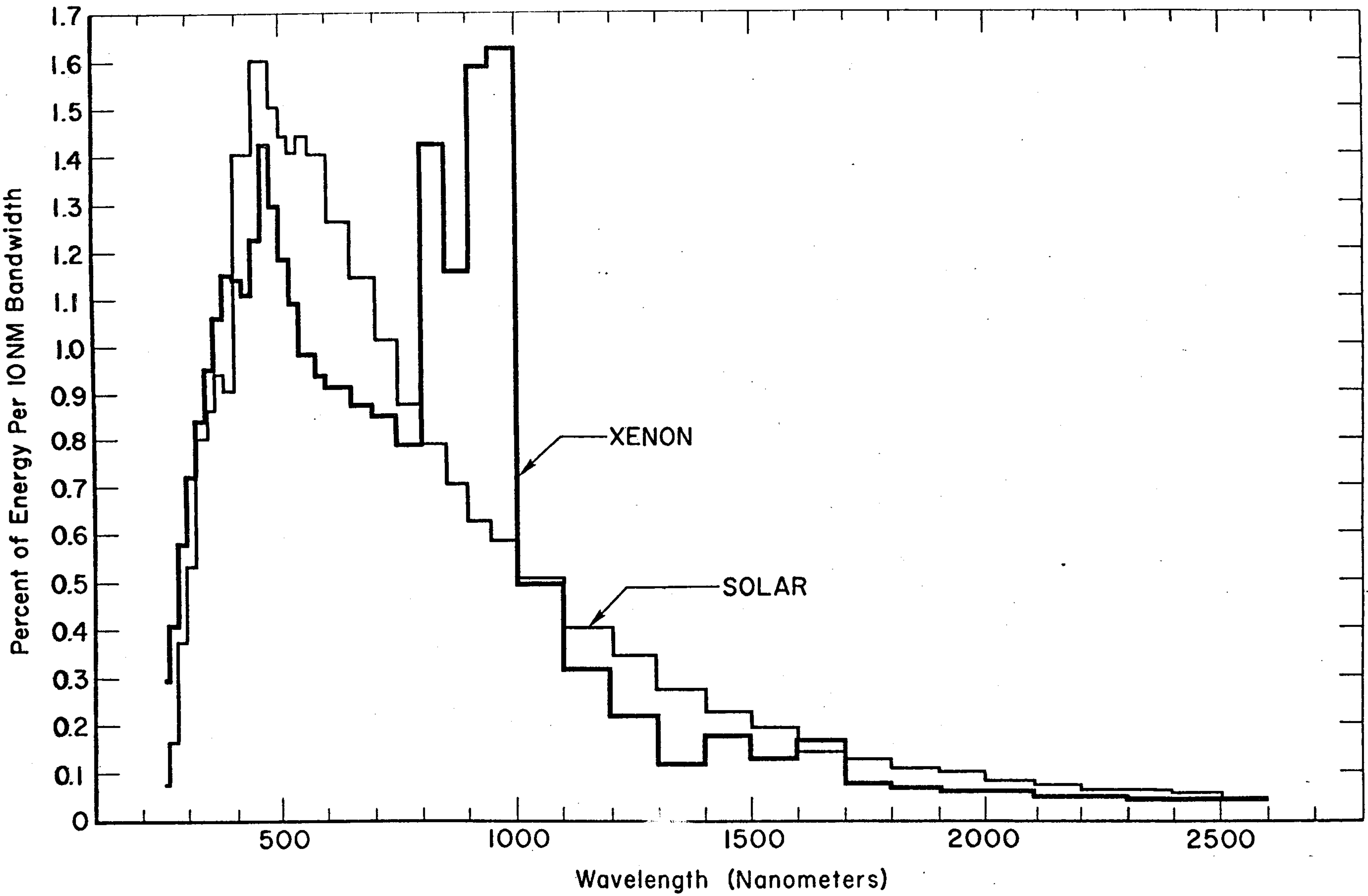


Figure 9 - Comparison of Xenon Spectrum with Solar.

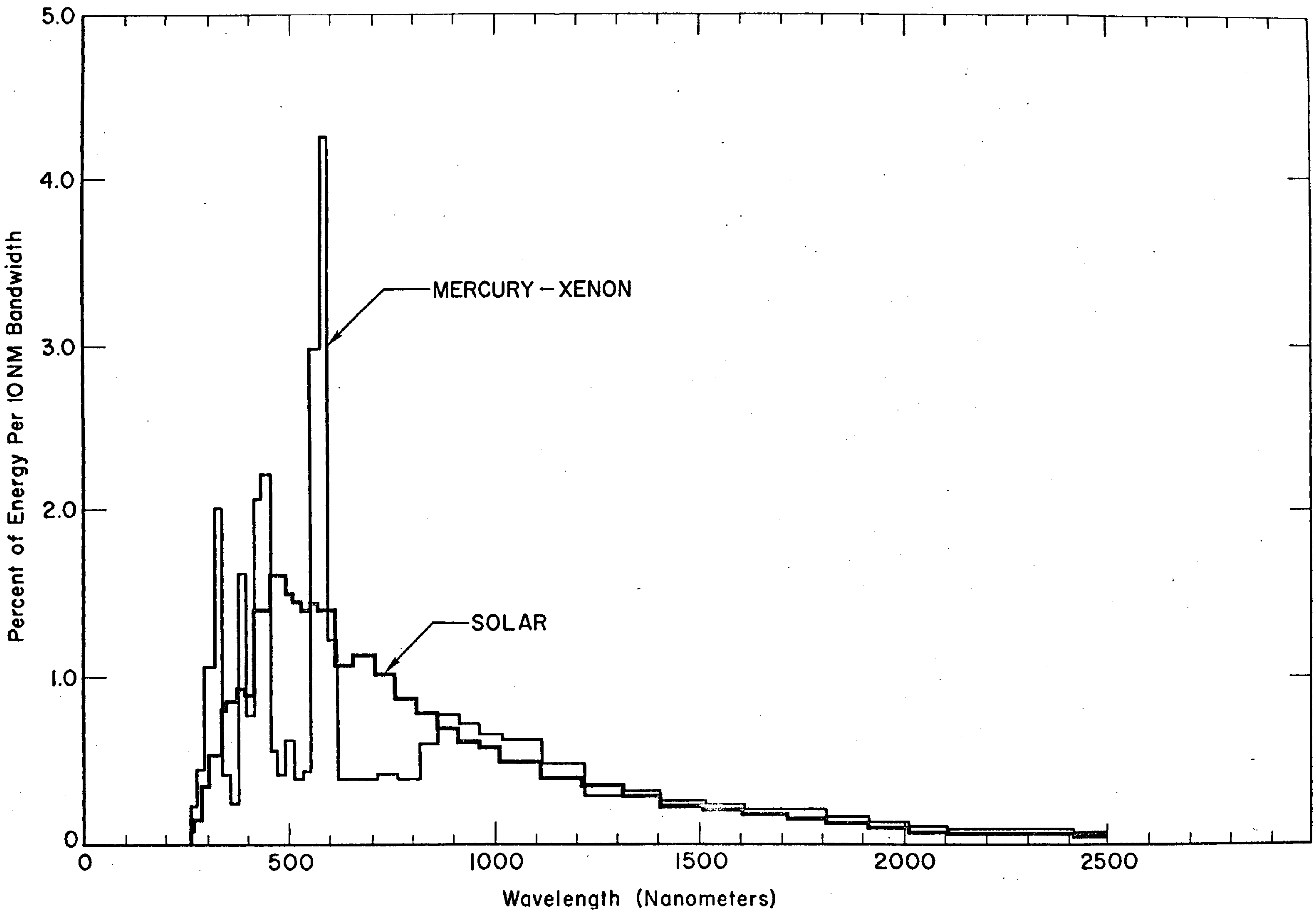


Figure 10 - Comparison of Mercury-Xenon Spectrum with Solar.